

1 What is claimed is:

- 2 1. A method of forming a crystalline ribbon, the method comprising:
 - 3 providing a mesa crucible having a top surface and edges defining a boundary of
 - 4 the top surface of the mesa crucible;
 - 5 forming a melt of a source material on the top surface of the mesa crucible, edges
 - 6 of the melt retained by capillary attachment to the edges of the mesa crucible; and
 - 7 pulling a crystalline ribbon from the melt.
- 8
- 9 2. The method of claim 1, wherein the pulling step comprises:
 - 10 placing a seed in the melt;
 - 11 pulling the seed from the melt between a pair of strings positioned along the edges
 - 12 of the crystalline ribbon, thereby solidifying the melt between the pair of strings to form
 - 13 the crystalline ribbon; and
 - 14 continuously pulling the crystalline ribbon from the melt.
- 15
- 16 3. The method of claim 1, wherein at least a portion of a boundary profile of the melt is
- 17 concave downward prior to the pulling step.
- 18
- 19 4. The method of claim 1, wherein at least a portion of a boundary profile of the melt is
- 20 concave downward outside the region of the crystalline ribbon.
- 21
- 22 5. The method of claim 1, wherein pulling the crystalline ribbon from the melt forms an
- 23 inflection point in a cross-sectional boundary profile of the melt.
- 24
- 25 6. The method of claim 1 further comprising forming a substantial portion of the melt
- 26 above the edges of the mesa crucible.
- 27
- 28 7. The method of claim 1 further comprising forming more than one crystalline ribbon.
- 29

- 1 8. The method of claim 5, wherein the inflection point in at least a portion of the cross-
2 sectional boundary profile of the melt predisposes the crystalline ribbon to grow
3 substantially flat.
4
- 5 9. The method of claim 1 further comprising replenishing the source material on the top
6 surface of the mesa crucible for continuous crystalline ribbon growth.
7
- 8 10. The method of claim 1 further comprising controlling the temperature of the mesa
9 crucible while forming the crystalline ribbon.
10
- 11 11. An apparatus for forming a crystalline ribbon, the apparatus comprising a mesa crucible
12 having edges defining a boundary of a top surface of the mesa crucible, the mesa crucible
13 retaining edges of a melt by capillary attachment to the edges of the mesa crucible.
14
- 15 12. The apparatus of claim 11 further comprising a pair of strings positioned along the edges
16 of the crystalline ribbon, the pair of strings defining a region within which a crystalline
17 ribbon is formed.
18
- 19 13. The apparatus of claim 11, wherein a portion of a boundary profile of the melt is concave
20 downward prior to forming a crystalline ribbon.
21
- 22 14. The apparatus of claim 11, wherein a portion of a boundary profile of the melt is concave
23 downward outside the region of a crystalline ribbon.
24
- 25 15. The apparatus of claim 11, wherein pulling a crystalline ribbon from the melt forms an
26 inflection point in a cross-sectional boundary profile of the melt.
27
- 28 16. The apparatus of claim 11, wherein a substantial portion of the melt is above the edges of
29 the mesa crucible.
30

- 1 17. The apparatus of claim 12, further comprising more than one pair of strings positioned
2 along the edges of more than one crystalline ribbon, each pair of strings defining a region
3 within which a seed disposed in the melt is pulled to form a crystalline ribbon.
4
- 5 18. The apparatus of claim 11, wherein the mesa crucible comprises graphite.
6
- 7 19. The apparatus of claim 11, wherein the edges of the mesa crucible define a recessed top
8 surface of the mesa crucible.
9
- 10 20. The apparatus of claim 11, wherein the width of the mesa crucible is between about 15
11 mm and about 30 mm.
12
- 13 21. The apparatus of claim 11, further comprising means for replenishing the melt on the top
14 surface of the mesa crucible for continuous crystalline ribbon growth.
15
- 16 22. The apparatus of claim 11, further comprising means for controlling the temperature of
17 the mesa crucible while forming a crystalline ribbon.
18
- 19 23. A method of forming a crystalline ribbon, the method comprising:
20 providing a crucible having a top surface and edges defining a boundary of the top
21 surface of the crucible;
22 forming a melt of a source material on the top surface of the crucible, the melt
23 having a boundary profile at least a portion of which is concave downward; and
24 pulling a crystalline ribbon from the melt.
25
- 26 24. The method of claim 23, wherein the pulling step comprises:
27 placing a seed in the melt;
28 pulling the seed from the melt between a pair of strings positioned along the edges
29 of the crystalline ribbon, thereby solidifying the melt between the pair of strings to form
30 the crystalline ribbon; and

continuously pulling the crystalline ribbon from the melt.

25. The method of claim 23, wherein the portion of the boundary profile of the melt is concave downward prior to the pulling step.

26. The method of claim 23, wherein the portion of the boundary profile of the melt is concave downward outside the region of the crystalline ribbon.

27. The method of claim 23, wherein pulling the crystalline ribbon from the melt forms an inflection point in a cross-sectional boundary profile of the melt.

28. The method of claim 23 further comprising forming a substantial portion of the melt above the edges of the crucible.

29. The method of claim 23 further comprising forming more than one crystalline ribbon.

30. The method of claim 27, wherein the inflection point in at least a portion of the cross-sectional boundary profile of the melt predisposes the crystalline ribbon to grow substantially flat.

31. The method of claim 23 further comprising replenishing the source material on the top surface of the crucible for continuous crystalline ribbon growth.

32. The method of claim 23 further comprising controlling the temperature of the crucible while forming the crystalline ribbon.

33. The method of claim 23, wherein the width of the crucible is between about 15 mm and about 30 mm.

34. The method of claim 23, wherein the crucible is a mesa crucible.

- 1
- 2 35. A method of forming a crystalline ribbon, the method comprising:
- 3 providing a crucible having a top surface and edges defining a boundary of the top
- 4 surface of the crucible;
- 5 forming a melt of a source material on the top surface of the crucible, the melt
- 6 having a boundary profile; and
- 7 pulling a crystalline ribbon from the melt, thereby forming an inflection point in at
- 8 least a portion of a cross-sectional boundary profile of the melt.
- 9
- 10 36. The method of claim 35, wherein the pulling step comprises:
- 11 placing a seed in the melt; and
- 12 pulling the seed from the melt between a pair of strings positioned along the edges
- 13 of the crystalline ribbon, thereby solidifying the melt between the pair of strings to form
- 14 the crystalline ribbon; and
- 15 continuously pulling the crystalline ribbon from the melt.
- 16
- 17 37. The method of claim 35, wherein a portion of the boundary profile of the melt is
- 18 concave downward prior to the pulling step.
- 19
- 20 38. The method of claim 35, wherein a portion of the boundary profile of the melt is
- 21 concave downward outside the region of the crystalline ribbon.
- 22
- 23 39. The method of claim 35 further comprising forming a substantial portion of the melt
- 24 above the edges of the crucible.
- 25
- 26 40. The method of claim 35 further comprising forming more than one crystalline ribbon.
- 27
- 28 41. The method of claim 35, wherein the inflection point in at least a portion of the cross-
- 29 sectional boundary profile of the melt predisposes the crystalline ribbon to grow
- 30 substantially flat.

- 1
- 2 42. The method of claim 35 further comprising replenishing the source material on the top
- 3 surface of the crucible for continuous crystalline ribbon growth.
- 4
- 5 43. The method of claim 35 further comprising controlling the temperature of the crucible
- 6 while forming the crystalline ribbon.
- 7
- 8 44. The method of claim 35, wherein the width of the crucible is between about 15 mm and
- 9 about 30 mm.
- 10
- 11 45. The method of claim 35, wherein the crucible is a mesa crucible.
- 12
- 13 46. A method of forming a crystalline ribbon, the method comprising:
- 14 providing a crucible having a top surface and edges defining a boundary of the
- 15 top surface of the crucible;
- 16 forming a melt of a source material on the top surface of the crucible, a substantial
- 17 portion of the melt above the edges of the crucible; and
- 18 pulling a crystalline ribbon from the melt.
- 19
- 20 47. The method of claim 46, wherein the pulling step comprises:
- 21 placing a seed in the melt; and
- 22 pulling the seed from the melt between a pair of strings positioned along the edges
- 23 of the crystalline ribbon, thereby solidifying the melt between the pair of strings to form
- 24 the crystalline ribbon; and
- 25 continuously pulling the crystalline ribbon from the melt.
- 26
- 27 48. The method of claim 46, wherein a portion of a boundary profile of the melt is
- 28 concave downward prior to the pulling step.
- 29

- 1 49. The method of claim 46, wherein a portion of a boundary profile of the melt is
2 concave downward outside the region of the crystalline ribbon.
3
- 4 50. The method of claim 46 wherein pulling the crystalline ribbon from the melt forms an
5 inflection point in a cross-sectional boundary profile of the melt.
6
- 7 51. The method of claim 46 further comprising forming more than one crystalline ribbon.
8
- 9 52. The method of claim 50, wherein the inflection point in at least a portion of the cross-
10 sectional boundary profile of the melt predisposes the crystalline ribbon to grow
11 substantially flat.
12
- 13 53. The method of claim 46 further comprising replenishing the source material on the top
14 surface of the crucible for continuous crystalline ribbon growth.
15
- 16 54. The method of claim 46 further comprising controlling the temperature of the crucible
17 while forming the crystalline ribbon.
18
- 19 55. The method of claim 46, wherein the width of the crucible is between about 15 mm and
20 about 30 mm.
21
- 22 56. The method of claim 46, wherein the crucible is a mesa crucible.
23
- 24 57. A method of controlling temperature of a mesa crucible while forming a crystalline
25 ribbon, the method comprising:
26 positioning an insulator comprising movable elements along a mesa crucible;
27 disposing the mesa crucible in a furnace; and
28 creating controlled heat leaks by moving the moveable elements of the insulator
29 relative to the mesa crucible.
30

- 1 58. The method of claim 57, wherein rods connected to the moveable elements penetrate the
2 furnace and are controlled from outside the furnace.
3
- 4 59. An apparatus for controlling temperature of a mesa crucible while forming a crystalline
5 ribbon, the apparatus comprising:
6 a mesa crucible disposed within a furnace;
7 an insulator comprising movable elements disposed along the mesa crucible; and
8 means for moving the moveable elements of the insulator relative to the mesa
9 crucible to create controlled heats leaks.
10
- 11 60. A method of replenishing a melt of a source material on a mesa crucible, the method
12 comprising distributing a source material onto a mesa crucible, thereby reducing the heat
13 load required to melt the source material.
14
- 15 61. The method of claim 60, wherein the distributing step comprises:
16 positioning a feeder at a distance from a mesa crucible;
17 moving a feeder in a first direction and a second direction along a mesa crucible;
18 and
19 vibrating the feeder during motion in at least one of the first direction and the
20 second direction, such that a source material disposed within the feeder enters a melt on
21 the mesa crucible during such motion.
22
- 23 62. The method of claim 61, further comprising melting the source material prior to source
24 material from a subsequent motion in the first direction reaching the melt.
25
- 26 63. The method of claim 61, wherein the distance from the mesa crucible is less than the
27 width of the mesa crucible.
28

- 1 64. An apparatus for replenishing a melt of a source material on a mesa crucible, the
2 apparatus comprising means for distributing a source material onto a mesa crucible,
3 thereby reducing the heat load required to melt the source material.
4
- 5 65. The apparatus of claim 64, wherein the means for distributing comprises:
6 a feeder positioned at a distance from a crucible, the feeder movable in a first
7 direction and a second direction along the crucible; and
8 means for vibrating the feeder during motion in at least one of the first direction
9 and the second direction, such that a source material disposed within the feeder enters the melt
10 during such motion.
11
- 12 66. The apparatus of claim 65, wherein the feeder comprises a tube for delivering the source
13 material to the melt.
14
- 15 67. The apparatus of claim 65, wherein the distance from the mesa crucible is less than the
16 width of the mesa crucible.
17
- 18 68. An apparatus for forming a crystalline ribbon, the apparatus comprising:
19 a crucible for retaining a melt having a boundary profile, the crucible having a
20 top surface and edges defining a boundary of the top surface of the crucible; and
21 means for pulling a crystalline ribbon from the melt, wherein at least a portion of
22 the boundary profile is concave downward.
23
- 24 69. An apparatus for forming a crystalline ribbon, the apparatus comprising:
25 a crucible for retaining a melt having a boundary profile, the crucible having a
26 top surface and edges defining a boundary of the top surface of the crucible; and
27 means for pulling a crystalline ribbon from the melt, thereby forming an inflection
28 point in at least a portion of a cross-sectional boundary profile of the melt.
29
- 30 70. An apparatus for forming a crystalline ribbon, the apparatus comprising:

1 a crucible for retaining a melt having a boundary profile, the crucible having a
2 top surface and edges defining a boundary of the top surface of the crucible; and
3 means for pulling a crystalline ribbon from the melt, wherein a substantial portion
4 of the melt is above the edges of the crucible.
5